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Disposition of fluid from Livestock Protection Collars following coyote attacks on collared goats

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Abstract

We estimated the amount of fluid from Livestock Protection Collars (LPCs) that was ingested by coyotes during attacks on domestic goats (*Capra hircus*). The minimum dose coyotes received from both small (30 ml) and large (60 ml) LPCs was 0.1 ml, although the average amount of fluid ingested by coyotes was 1.0 and 4.9 ml for the small and large LPCs, respectively. Secondarily, we also determined (1) that once an LPC bladder was punctured, 85–90% of the fluid was dispensed, and (2) the amount of LPC fluid retained on the skin and wool of the animal attacked, averaged 7.5 and 12.7 ml for small and large LPCs, respectively (range = 3.9–22.0 ml). On average, 56% of the LPC fluid dispensed during a coyote attack was not accounted for in these trials. Suggestions for enhancing the portion of LPC fluid ingested, and thereby reducing environmental risks and contamination, are presented.

Keywords: *Canis latrans*; Coyote; Goat; Livestock Protection Collar; Physiologic marker; Predation

1. Introduction

The Livestock Protection Collar (LPC, McBride, 1974), registered by the US Environmental Protection Agency for use with 10 mg active ingredient sodium monofluoroacetate per ml of solution (Moore, 1985), is a device designed to deliver a lethal dose of toxicant to coyotes (*Canis latrans*) that attack sheep (*Ovis aries*) or goats (*Capra hircus*, Connolly et al., 1978; Savarie and Sterner, 1979; Connolly, 1980; Burns et al., 1988; Connolly and Burns, 1990). The device, initially designed to be worn by sheep or goats weighing less than 25 kg, consists of a collar with 2 rubber packets, each containing 15 ml of the toxic solution. When coyotes attack sheep or goats by biting their throats and asphyxiating them (Connolly et al., 1976), they puncture one or both packets of the LPC and ingest a lethal dose of the toxicant. Since coyotes also attack larger sheep and goats, subsequent experiments were conducted with larger LPCs that cover a broader section of the throats of larger animals. This entailed using LPCs in which each packet contained 30 ml of toxicant. The large LPCs were never registered for use with 30 ml of toxicant but they are effective with the quantity registered for use with the small LPC (Burns et al., 1984, 1996; Anonymous, 1986).

We modified the LPC by replacing the toxicant with a physiological marking agent in order to identify characteristics of individual coyotes involved in attacks on livestock (Windberg et al., 1997). One prerequisite was knowledge of the amount of solution ingested by coyotes during such attacks. Our study was designed to determine (1) the total amount of fluid dispensed from the LPC, (2) the amount of fluid ingested by coyotes, and (3) the amount of LPC fluid contaminating the skin and hair of the livestock that were attacked.

Previous research included data related to all 3 of our objectives (Burns et al., 1984, 1988, 1996; Anonymous, 1986) but we were cautious about the prior results dealing with the amount of LPC fluid ingested by coyotes during attacks on livestock, an issue critical to our needs. The methodology in the earlier research assayed the concentration of fluoroacetate in muscle tissue to estimate the dose of compound 1080 received by the coyote. We were concerned uptake of the toxicant might be confounded by time to death which in cases is as short as 1.5 hours (Burns et al., 1984). Hence, we used a different methodology to evaluate this issue and

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secondarily supplemented information regarding the amount of fluid dispensed by both large and small LPCs as well as the amount of LPC fluid that contaminates livestock carcasses as a result of such attacks by coyotes.

2. Materials and methods

Our general approach involved using a stock solution with a radioisotope (^{131}I) marker (Knowlton et al., 1989). We dosed 1 series of coyotes with known quantities of the marker to develop a dose–response curve of radioactivity in the thyroids of the dosed animals. A second series of coyotes experienced in killing livestock were allowed to kill goats wearing LPCs containing known concentrations of the stock solution. The doses these coyotes ingested was estimated by determining the radioactivity in their thyroids and inserting that value into the regression equation from the dose–response curve from the first series of coyotes. Similarly, the amount of LPC fluid contaminating the goat carcasses was determined by comparing the amount of radioactivity on the capes (hide and hair of the head, neck, and shoulders) of goats killed by the coyotes with radioactivity on clean capes spiked with known quantities of the stock marker solution.

2.1. Coyotes

Twenty-seven adult coyotes (14 males, 13 females) from the captive colony at the United States Department of Agriculture research facility near Millville, Utah, USA, were used in this study. Twelve (6 males and 6 females) were used to develop the dose–response curve and 15 (8 males and 7 females) were used in the goat attack phase of the study. The coyotes weighed between 8.0 and 14.6 kg ($\bar{x} = 10.7$), were caged individually, and had been captured in the wild or born and raised in captivity. All coyotes appeared to be in good health and without physical injuries. The coyotes were maintained on a ration prepared for the local fur industry (Furbreeders Agricultural Cooperative, Logan, UT, USA). Those used in the livestock predation phase of the study were trained to kill livestock through a sequence of exposures to live rats, rabbits, kids, and/or adult goats. Coyotes were considered adequately prepared for this part of the study after they had killed two subadult or adult Angora goats within 1 week.

2.2. Angora goats

The Angora goats were acquired from a livestock auction and were of heterogenous breeding, age, weight (13.7–36.2 kg), and gender. They were allowed to graze in pastures separate from the coyotes except during LPC trials. Supplemental feed was provided 6 days a week; water was provided *ad libitum*.

2.3. Stock marker solution

The stock marker solution used throughout this study was formulated by diluting 8.4 mCi of ^{131}I radio-labeled sodium iodide (CAS No. 7790-26-3) (ICN Biomedicals, Inc., Irvine, CA) in 240 ml of physiologic saline (0.9%) solution. A radionuclidic purity of >99% was indicated by the vendor.

2.4. Dose–response equations

We developed two dose–response curves to provide a basis for interpreting the results obtained in the coyote-livestock predation tests. The first involved the relative amount of radioactivity concentrated in the thyroids of coyotes as a result of ingesting known quantities of the ^{131}I marker solution; the other involved the relative amount of radioactivity associated with known amounts of LPC fluid adhering to the skin and hair of the prey.

2.4.1. Calibration equation for ingested isotope

To establish an ingestion calibration curve, we assigned 3 coyotes to each of 4 treatments. The treatments were created by placing 0.0, 0.1, 0.5, or 2.5 ml of the stock isotope solution into cavities carved into a series of 4.5-g tallow baits. The liquid was allowed to evaporate and the cavities then refilled with additional melted tallow. To insure complete ingestion of the treatment dose (baits), we anesthetized each of the coyotes and as they recovered their swallowing reflexes, we introduced the bait containing the radioactive marker toward the back of their throat until they swallowed it. Ingestion was verified with an external radiation counter. The coyotes were held for 5 days after bait ingestion to allow the absorbed marker to accumulate in the thyroid glands and then euthanized with an intravenous injection of T-61 euthanasia solution. Both thyroid glands were excised from each coyote, placed in individually labelled vials, and stored under refrigeration until assayed for radiation.

2.4.2. Calibration equation for isotope spilled on goat capes

We obtained capes (skin and hair of the head, neck and shoulders) from 15 goats that had not been exposed to LPCs, or LPC marker solution. We spiked 3 capes each with 0.0, 1.0, 5.0, 10.0, or 30.0 ml of ^{131}I marker solution at the concentration used in the small LPCs (see Section 2.3). We placed the capes in individual 3.8-l jars and digested them by adding 2.2 l of a 50% (W/W) NaOH solution and allowing them to stand for several days. Contents of the jars were stirred periodically to insure complete digestion. The weight of material in each jar was determined immediately prior to taking samples for assay by subtracting the weight of each jar from the combined weight of the jar and its contents. After mixing the material in each jar to a homogeneous consistency, 3 × 10-ml samples were taken from each jar and placed in individual scintillation vials. The weight

of test material in each vial was determined by subtracting the weight of the vial from the gross weight of the filled vial. Samples were then stored pending radioactive assays.

2.5. The marking device (collar)

We used two sizes of LPCs (Rancher's Supply, Inc., Alpine, Texas, USA); a small LPC containing two bladders, or pouches, each capable of holding 15 ml of fluid and a larger collar in which each of the 2 bladders were capable of holding 30 ml of fluid. The LPC solution was prepared by mixing 5.0 g of tartrazine, F.D. & C. yellow dye #5 (Gardner, 1979; Burns and Savarie, 1989), in 1,000 ml of physiologic saline to provide a visual cue for spillage or contamination in subsequent tests. We wrapped each collar in absorbent toweling and placed it in an individual, labeled, self-sealing, double plastic bag.

Prior to being filled, we held each collar "package" overnight in a 21°C oven to facilitate sealing the bladder injection sites on the LPCs. On the morning it was used, each LPC package was removed from the oven and weighed to the nearest 0.1 g. Each bladder of the small LPCs was injected with 10 ml of physiologic saline with the visual marker and 5.0 ml of the radioactive stock solution. Each bladder of the larger LPCs was filled with 25 ml of solution with the visual marker and 5.0 ml of radioactive stock solution. The collars were re-wrapped in the original toweling, replaced in their double plastic bags, and weighed.

2.6. Coyote-goat predation tests

We conducted the livestock predation phase of the study by letting each of 10 coyotes become acclimated to a 1 ha pen and then introducing an Angora goat equipped with a small LPC. Five other coyotes were similarly allowed to kill Angora goats equipped with large LPCs. After each goat was killed or incapacitated, but before the coyote could feed on the carcass, the coyote was removed from the pen and returned to its holding kennel. Five days after it killed an LPC-equipped goat and punctured one or both packets on the LPC, the coyote was euthanized with an intravenous injection of T-61 euthanasia solution. Thyroids from these coyotes were excised, placed in clean scintillation vials, and refrigerated pending radioactive assay.

Immediately following removal of the coyote from the pen, we euthanized the goat if it had not been killed by the coyote. We then carefully removed the LPC from the goat, re-wrapped it in its original absorbent toweling, and replaced it in the double plastic bag in which it had been previously stored. Each LPC package was re-weighed. The difference between the pre- and post-test weights of each LPC was used as a measure of the LPC fluid dispensed by that collar during the predation test in which it was used. The quantity of fluid lost from the collar was converted from grams to milliliters (1 g = 1.06 ml) to facilitate comparisons with LPC fluid at other locations.

The goat carcass was recovered and taken to the laboratory where the cape, as well as the skin and hair from other portions of the body stained with the tartrazine marker (indicating contamination from the LPC), were removed and placed in an individual 3.8-l jar. Jar contents were then digested and sampled as described in Section 2.4.2. Samples were stored pending radioactive assays.

2.7. Analyses

Assays to determine the relative radiation from ^{131}I were conducted by placing the scintillation vials in the automatic feed tray of a deep-well gamma scintillation counter and accumulating radiation counts for 30 s on each vial. A Packard model 5320 autogamma spectrometer system was used with a fixed optimal spectrometer counting window (305–405, 20% ga h). Assays of all coyote thyroids (dosed coyotes and predation coyotes), as well as 3 samples from each digested goat cape (spiked and predation tests) were assayed within 3 h on the same day to preclude calculations to correct for radioactive decay.

Linear regression analyses for the ingestion dose–response curve and the cape contamination dose–response curve from capes spiked with known quantities of LPC marker solution were calculated. This allowed reverse regression analyses to estimate (1) the amount of LPC fluid ingested by coyotes when they attacked LPC-equipped goats and (2) the amount of LPC fluid that remained on the hair and skin of the goats after they were killed.

3. Results and discussion

All phases of this study were conducted in 1989, with dosing coyotes with measured quantities of ^{131}I on November 12; coyote–goat predation tests conducted between November 2 and 23; and clean goat capes spiked with measured quantities of LPC fluid on November 29. The latter were subsequently digested and then sampled on December 7 and 8. All samples were removed from storage and radiation counts were conducted on December 11.

3.1. Amount of fluid dispensed by LPCs

Failure to obtain a pre-test weight on 2 of the smaller LPCs precluded their use in determining the amount of fluid dispensed. The remaining 8 smaller LPCs lost from 11.9 to 27.8 ml of fluid ($\bar{x} = 19.2$ ml, Table 1). The distribution was bimodal, depending on whether the coyote punctured one or both pouches on the LPC. In the four cases where only 1 pouch was punctured, a mean of 13.0 ml of fluid was dispensed; whereas a mean of 25.4 ml was dispensed from the 4 collars where both pouches were punctured. In the 5

1988, 1996; Connolly and Burns, 1990). In our study, the quantity of fluid coyotes ingested while killing livestock averages only 4.3% and 14.1% of the fluid dispensed by the small and large LPCs (containing 30 and 60 ml fluid), respectively. The remainder of the fluid either adhered to the hide and hair of the victim or presumably was dispensed into the environment. Enhancing the portion of LPC fluid from LPCs that coyotes ingest should be desirable. Increasing the fraction of LPC fluid ingested presumably would allow a reduction in the concentration and/or quantity of toxicant in the LPC. Potential ways of enhancing ingestion of the LPC fluid dispensed include: (1) using a non-elastic pouch so the expelling pressure was created only by the clamping action of the coyote's jaws; (2) increasing the viscosity of the fluid so it would be dispensed more slowly; or (3) enhancing the flavor and odor of the fluid (Mason and McConnell, 1997) so coyotes might actively seek and ingest fluid that was spilled in act of killing the livestock. Toward this end, efforts to register the large LPC with 30 ml of fluid per packet was curtailed but use of the larger LPC with only 15 ml of toxicant per packet is approved for use.

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